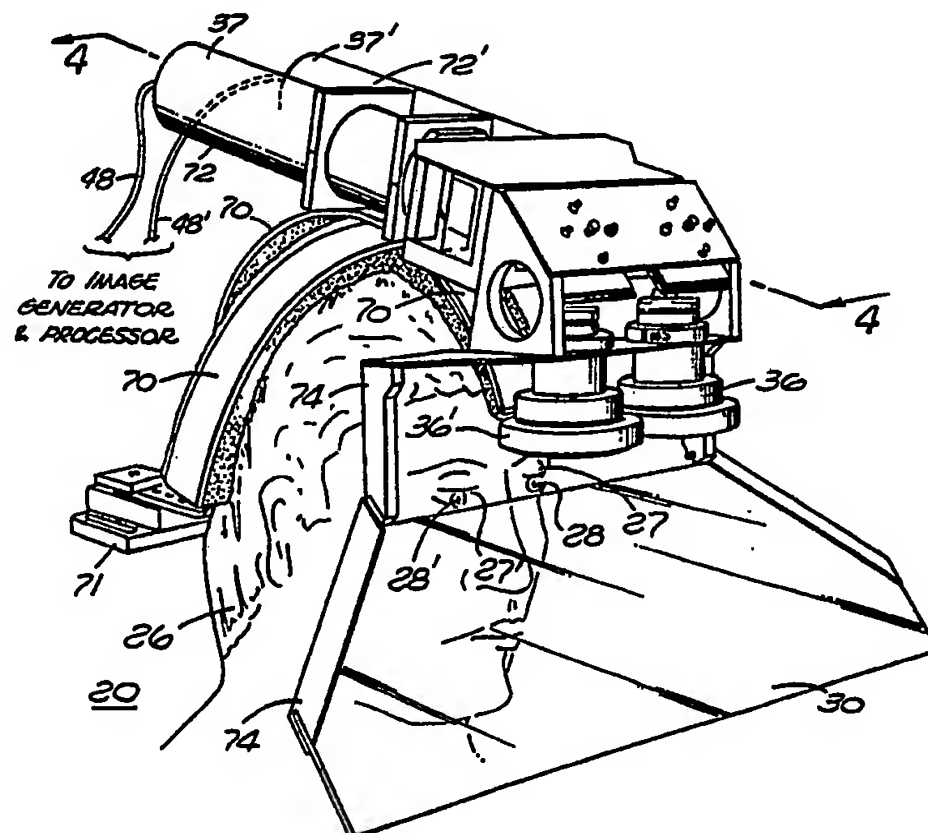


INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<p>(51) International Patent Classification ⁵ : G09G 3/02, G01C 21/00 G09B 9/08</p>	<p>A1</p>	<p>(11) International Publication Number: WO 92/18971 (43) International Publication Date: 29 October 1992 (29.10.92)</p>
<p>(21) International Application Number: PCT/US92/03226 (22) International Filing Date: 20 April 1992 (20.04.92) (30) Priority data: 690,173 22 April 1991 (22.04.91) US (71) Applicant: EVANS & SUTHERLAND COMPUTER CORP. [US/US]; 600 Komas Drive, Salt Lake City, UT 84108 (US). (72) Inventor: FISHER, Ralph, W. ; 7411 North Hitching Post Drive, Park City, UT 84060 (US). (74) Agent: NILSSON, Byard, G.; Nilsson, Wurst & Green, 707 Wilshire Boulevard, Suite 3200, Los Angeles, CA 90017 (US).</p>		<p>(81) Designated States: CA, DE, GB, JP. Published <i>With international search report.</i></p> <p style="text-align: center; font-size: 1.2em;">BEST AVAILABLE COPY</p>

(54) Title: **HEAD-MOUNTED PROJECTION DISPLAY SYSTEM FEATURING BEAM SPLITTER**



(57) Abstract

A head-mounted projection display system (20) featuring a beam splitter (30) displays a simulated environment to an observer (26) using a light-weight, low cost, head-mounted projector and a retro-reflective screen (32). The display system optically collocates the projector with the observer's eyes (27) for effective use of either curved or flat retro-reflective screens. High screen gain achieved by the head-mounted projection display system (20) makes inexpensive projector sources such as a cathode ray tube (37) feasible. An alternative head-mounted display system also incorporating beam splitters producing unlimited horizontal field of view but with limited binocular overlap while using multiple head-mounted image sources for each eye is described. A method of providing the head-mounted display system also is disclosed.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	FI	Finland	ML	Mali
AU	Australia	FR	France	MN	Mongolia
BB	Barbados	GA	Gabon	MR	Mauritania
BE	Belgium	GB	United Kingdom	MW	Malawi
BF	Burkina Faso	GN	Guinea	NL	Netherlands
BG	Bulgaria	GR	Greece	NO	Norway
BJ	Benin	HU	Hungary	PL	Poland
BR	Brazil	IE	Ireland	RO	Romania
CA	Canada	IT	Italy	RU	Russian Federation
CF	Central African Republic	JP	Japan	SD	Sudan
CG	Congo	KP	Democratic People's Republic of Korea	SE	Sweden
CH	Switzerland	KR	Republic of Korea	SN	Senegal
CI	Côte d'Ivoire	LI	Liechtenstein	SU	Soviet Union
CM	Cameroon	LK	Sri Lanka	TD	Chad
CS	Czechoslovakia	LU	Luxembourg	TG	Togo
DE	Germany	MC	Monaco	US	United States of America
DK	Denmark	MG	Madagascar		
ES	Spain				

"HEAD-MOUNTED PROJECTION DISPLAY SYSTEM FEATURING BEAM
SPLITTER"

5

BACKGROUND OF THE INVENTION

The present invention relates to a head-mounted projection display system providing a wide field of view with unlimited binocular overlap or unlimited field of view through limited binocular overlap, more particularly to both systems featuring a beam splitter.

Experience is expensive. Particularly, when the experience involves the man-machine interface between a skilled pilot and a multi-million dollar aircraft.

Today's high performance aircraft have become more and more complex, and a need exists for more extensive specialized pilot training. To obtain such training an inexperienced pilot, commercial or military, must either actually be trained in the aircraft he is to fly or be provided with training in a simulator for that aircraft.

However, there are certain emergency procedures and maneuvers that, as a practical matter, simply cannot be experienced by training in an actual aircraft because of the real life danger of pilot injury or structural damage. Consequently, as a practical matter, some situations can only be experienced in a

simulator. This is particularly true of maneuvers that involve emergency procedures.

Aircraft simulators are called upon to take on more and more of the aircraft training mission. For such training to be effective, the aircraft simulator must faithfully reproduce the simulated environment that the pilot trainees face in an actual flight. The pilot must "see" the terrain over which he flies. He must appreciate obstacles on the ground as well as in the air. Through his eyes, his brain must assimilate visual images and cues received from the simulated environment surrounding his craft.

The desire to more effectively support pilot vision in both a field of view and image resolution of the simulated environment has led to the development of a wide variety of simulator display concepts.

One approach provides a projection simulator display achieving wide field of view by incorporating several large, expensive projectors collectively producing an image on the inside of a 20 to 40 foot dome to be viewed by an observer located close to the dome center.

The United States Patent No. 4,657,512, issued April 14, 1987 to R. A. Mecklenborg, entitled, "Visual System with Filter for a Simulator", describes a vehicle simulator display system for training two observers such as a pilot and co-pilot seated side-by-side viewing compound images projected on a large curved screen. Structurally, the display system includes two projectors, each of which uses a polarizer to polarize the individual light images in opposite directions in a circular manner. The vehicle simulator display system of the Mecklenborg patent uses two large off screen projectors pointed at a large dome-like reflective screen. A reflective viewing screen is curved and

5 specially treated to reflect impinging light energy. The
Mecklenborg display system provides a wide field of view
to the screen observers. However, the cost of an
overall display system is exorbitant due to the large
off-screen projectors and domed retro-reflective screen.
And, the conventional multiple projector process
produces only reasonable scene brightness.

10 An alternative method, using head or helmet-
mounted displays, reduces the overall system cost and
enables increasing projected scene brightness by
projecting the simulated image directly into the
observer's eyes.

15 The United States Patent No. 4,349,815 issued
September 14, 1982 to A. M. Spooner, entitled, "Head-
Movable Frame-Scanner for Head-Coupled Display",
describes a helmet-mounted display system using a curved
retro-reflective screen and two image projectors.

20 Unfortunately, in the inexpensive helmet-
mounted system, the requirements for comfortable
observer viewing, good eye relief, reasonable pupil size
and full binocular viewing are not compatible with the
desired wide fields of view. Field of view for a
helmet-mounted display system conventionally is limited
to 20 to 60 degrees for each eye. Visual fields
25 traditionally have been achieved only by providing each
eye with a separate field that results in limited
binocular overlap.

30 It would be advantageous to combine the best
features of both the projection and the helmet-mounted
displays to produce a wide field of view display
providing comfortable observer viewing and low overall
system cost.

SUMMARY OF THE INVENTION

5 The present invention provides a head-mounted projection display system featuring a beam splitter that resolves the problem of high cost and the narrow field of view attendant with conventional head mounted image display systems.

10 Using direct image display into the eyes of an observer, this invention produces simulated viewing of pre-prepared events in a low cost, effective manner with a wide field of view.

15 More particularly, the invention provides a head-mounted projection display system that has; a head mount worn by an observer, a head position sensor coupled to the head mount to provide angular position signals indicative of the observer's angular head position, an image generator to receive the angular position signals and generate display signals of binocular images, a transmitter that receives the generated display signals, and a beam splitter
20 selectively transmissive, connected to the head mount to reflect the binocular images to a retro-reflective viewing screen, then pass the images from the retro-reflective screen back into the observer's eyes.

25 An alternative embodiment provides for a head-mounted projection display system that has; a head mount worn by an observer, a head position sensor coupled to the head mount to provide angular position signals indicative of the observer's angular head position, at least one image generator for each eye of the observer
30 to receive the angular position signals and generate display signals of binocular images, a transmitter that receives the generated display signals and at least one beam splitter for each eye, selectively transmissive positioned at different angles one from another,
35 connected to the head mount to reflect the binocular

representative; yet in that regard, they are deemed to afford the best embodiment for purposes of disclosure and to provide a basis for the claims herein which define the scope of the present invention.

5 As shown in the accompanying figures, the head-mounted projection display system includes; a head-mounted projector, image generator and processor, a head position sensor, one or more beam splitters and a retro-reflective screen. Note that these elements of the
10 system are well known individually and therefore are not disclosed in structural detail.

 The head-mounted projectors receive identical images from a projector source that is connected to receive signals for a dynamic image generated by the
15 image processor. Accordingly, the projector reduces the display signals to a pair of binocular images and projects these images while a processor evaluates feed back from a head position sensor and compensates for angular head position changes made by the observer. The
20 projected binocular images are partially reflected from the beam splitter toward a retro-reflective screen. The retro-reflective screen reflects back the images directly into the observer's eyes, through the beam splitter.

25 By incorporating two head-mounted projectors into the head-mounted projection display system, specifically, one for each eye, binocular overlap of the images reflected from the screen is unlimited. Consequently, the observer experiences a wide and
30 natural field of view.

 Fig. 1 is a schematic representation side view of the head-mounted projection display system 20 featuring the beam splitter 30. The head-mounted projection display system 20 can be easily mounted onto
35 a helmet, or other head mount not shown here. A head-

mounted projector apparatus 21 incorporates a cathode ray tube 36 that projects binocular light beams 34 produced by the image generator and processor 22. In one embodiment, the light beams 34, a 5 mm cone of light, is focused through lens 36 into a point of light striking the beam splitter 30 which functions as a selectively reflecting surface transmitting approximately fifty percent of the reflected light beam 34' to the retro-reflective screen 32. A normal reflective screen will not return much of the projected image to the eye. Consequently, fifty percent of the light energy 34 is lost by the beam splitter 30, here. The light beam 34' bounces back through the beam splitter 30 into the eyes 27 of the observer 26 as an image beam 34''. The return reflected image beam 34'' is fifty percent of the beam reflected. The screen-reflected image beam 34'' appears to the observer 26 as an image projected within the observer's 26 eyes 27.

In operation, the observer 26 wearing the head-mounted projection display system 20 sees the light beam 34' striking the screen surface 32 and the resultant image beam 34'' striking his eye 27. Another observer not wearing the head-mounted apparatus 21 will not see the images. The observer 26 can move his eyes 27 within a 1/2" range, up, down left or right and still see the image beam 34'', because the image beam 34'' is projected directly onto the observer's pupil 28. The image beam 34'' is approximately twenty-five percent of the generated light beam 34.

Because the projected beams are oriented with the observer's 26 head, linear head motion along or normal to the optical axis by the observer 26 does not affect the observer's viewing of the projected images. The image beams 34'' will appear to the observer 26 to move with his linear head motion exactly as if there

were an infinite distance separating the projected images from the observer 26. The illusion is maintained during image simulation of an infinite distance between the observer 26 and the projected image while the observer's eyes 27 are focusing on the image on the retro-reflective screen 32.

In the head-mounted projection display system 20 of Fig. 1, angular head motion by the observer 26 must be compensated. The head position sensor 24 controls the image generator and processor 22 determining where detail within the image beam 34'' must move to provide correct perspective within the infinite viewing distance for the observer 26. Specifically, feedback signals are provided through a line 25 from the head position sensor 24 for processing in the image generator and processor 22. Angular motion compensation is received by the head-mounted projection system 21 through data bus 48. In this example, the data bus 48 is a wire.

As suggested above, the image beams 34, 34' and 34'' carry one of a pair of binocular images. The two sets of beams are shown more clearly in Fig. 2. Image beam 34''' represents the 50 percent of image beam 34 lost through the selectively transmissive beam splitter.

Fig. 2 is a schematic representation top view of an image projected from a head-mounted projection display system having unlimited binocular overlap.

The single beamsplitter concept as described in Figures 1, 2, 3 and 4 provides unlimited binocular overlap, but limited field view. The concept as shown in top view Fig. 2 uses two image generators, here cathode ray tubes (CRT) to obtain these fields of view. The image projected from CRT 37 enters background optical relay 33 and is split into two images by

combining optics 100. These two identical images are projected simultaneously by the two projection lenses 36, 36' through beamsplitter 30 toward flat or curved retro-reflective screen 32. These two identical images 34, 34' impinge the screen 32 and are returned from the retro-reflective screen to each eye 27, 28.

This wide field of view image is projected at a range of approximately 120° to 140° horizontally. However, it is of low resolution, for example approximately 8 arc minutes of resolution. The other projector, CRT 37' also projects two images, utilizing a different optical relay. An inset relay 33' projecting a narrow field of view of for example approximately 40° to both eyes 27, 27' provide images having a high resolution of approximately 2 arc minutes. The use of background relay and inset relay optics produce an image display to the observer 26 that have both wide field supporting his peripheral vision and high resolution at the center of the image display. This high resolution area is commonly called the observer's 26 "area of interest", or inset region while the observer's wider field of view is referred to as his background region.

In Fig. 2, two separate cathode ray tubes 37, 37' each project to both the observer's 26 right and left eyes 27. Cathode ray tube 37' projects a narrow field, high resolution light beam 66, 66' to both of the observer's eye pupils 28 through a single beam splitter 30. Simultaneously cathode ray tube 37 projects a wide field light beam 64, 64' through beam splitter 30 to both the observer's eyes 27, 27'. As shown in Fig. 2 the observer 26 views the image beams 64, 64', 66 and 66' as left background image (LB), right background image (RB) left insert image (LI) and right insert image (RI) respectively.

Fig. 3 is an orthogonal partial view of a head-mounted projection display system 20, shown with a cross section taken along line IV-IV through the left eye 28 of the observer 26. The observer 26 wears the head-mounted projection display system 20 shown here on support mounting band 70. The observer's left eye 27 and right eye 27' view the screen (not shown here) through beam splitter 30 which is held by a beam splitter support bracket 74. Projection lens' 36, 36' are positioned above the beam splitter 30. Cathode ray tube covers 72, 72' are mounted to the support mounting band 70. Light images as electrical signals are received by the cathode ray tubes (not shown here) housed within the cathode ray tube covers 72, 72' through electrical wires 48, 48'. Counter weights 71 counter balance the weight of the beam splitter 30 and projection lenses 36 or 36' facilitating the position of the head-mounted projection display system 20 on the head of observer 26.

Fig. 4 is an offset vertical cross section view taken along the plane of a line IV-IV of the head-mounted projection display system of Fig. 3. The head-mounted display system 20 with unlimited binocular overlap projects an image 34'' to the pupil 28 of the observer's eye 27. A flat screen 32', shown in this example, reflects through beam splitter 30 into the observer's left pupil 28 the light beam 34 emitted from lens 36 and cathode ray tube 37 through an optical relay 33. The light beam 34' is selectively reflected through the beam splitter 30 where fifty percent of the light energy 34''' is lost and is viewed by the observer from screen 32' as image beam 34''. The left cathode ray tube cover 72 contains the cathode ray tube 37, optical relay 33, a series of lens or a fiber optic bundle coupling half of the output from the cathode ray tube 37

to lens 36 mounted on the observer's head. One half of the light from the CRT is coupled to the other projection lens 36'.

5 This head-mounted projection display system offers the best advantages of projection dome displays, such as large field of view, good eye relief, good pupil size and full binocular view plus the low cost and small size of the helmet-mounted direct view display.

10 An alternative embodiment of the head mounted projection system 20' is shown in Fig. 5. This system 20' requires a separate projection cathode ray tube for each eye 27, 27' because dual beamsplitters 30, 30' either one piece or two pieces are positioned at different angles over each eye. For example, the beam
15 splitters 30, 30' would be positioned inclined in the vertical plane 45° while inclined in the horizontal plane 90° to the observer's eyes. These angles are approximate in nature and can vary in a range of 10° plus or minus. The combining optics of the system
20 described in detail by Figures 1, 2, 3 and 4 are eliminated from this design. The embodiment of Fig. 5 has the advantage of providing unlimited field of view with limited binocular overlap. The necessity of adding an inset image would increase the number of projectors
25 used from two projectors to four. Therefore, this system 20' provides a concept that is physically heavier, more complex and ultimately more costly than the system 20 described in Figures 1, 2, 3 and 4. Four distinct and separate image generators, here cathode ray
30 tubes, would provide four slightly different images but with added system cost and weight.

The head mounted projection display system 20' shown more clearly in Fig. 5 has a vertical field of view theoretically limited by the beam splitters 30, 30' to 90°. Images as electrical signals enter the
35

projectors 37, 37' through electrical wires 48, 48'.
Image beams 62 and 60 are emitted from projection lenses
36, 36' respectively. The image beams 60, 62 impinge
the retroreflective screen 32, shown covered in this
5 example. The observer 26, with his left eye 27 and
right eye 27' views a right eye field of view A and a
left eye field view of B, respectively reflected from
flat or curved retroreflective screen 32. Binocular
overlap region C is the region viewed by observer 26
10 where A and B overlap.

Hence, as shown in the embodiment of Figures
2, 3 and 4, the optical collocation of the projectors
for the observer's pupils 28, 28' provides the observer
26 with a wider field of view. However, the horizontal
15 field of view is still limited to 120° to 140°. This
horizontal field limitation can be eliminated through
the alternative embodiment shown in Fig. 5 however, full
binocular coverage for the observer suffers.

Another advantage is the head-mounted
20 projection display system's insensitivity to screen
surface imperfections. These imperfections which
traditionally occur in different areas of the two
pictures projected upon the screen are thus ignored by
the observer's brain. Consequently an expensive,
25 continuous, high quality dome surface is not required as
with conventional wide field of view projection
simulator displays. Simple, flat panel screen surfaces
are adequate to provide wide field of view projection
simulation. For example, a basic one frequency
30 icosahedron, provides unlimited field of view capability
for the described head-mounted projection display
system.

The head-mounted projection display system
described herein has been directed toward flight
35 simulators and the like. However, it is not outside the

scope of the disclosed projection system to be employed in any environmental simulation including, but not limited to; video games, land based vehicles, motion pictures or any other video graphic displays.

5

In view of the above explanation of the exemplary system, it will be appreciated that embodiments of the present invention may be employed in many different applications to achieve for an observer an unlimited field of view while wearing the head mounted projection display system featuring a beam splitter and limited binocular overlap. While certain exemplary structures and operations have been described herein, the appropriate scope hereof is deemed to be in accordance with the claims as set forth below.

10

WHAT IS CLAIMED IS:

- 1 1. A head-mounted projection display system for
2 use with a viewing screen for providing a display to an
3 observer, comprising:
4 a head mount to be worn by the
5 observer;
6 a head position sensor means coupled to
7 said head mount for providing angular position
8 signals indicative of the angular position of
9 the observers head;
10 an image generator means providing
11 display signals representative of binocular
12 dynamic displays for said observer and
13 connected to receive said angular position
14 signals;
15 at least one binocular image means
16 affixed to said head mount connected to
17 receive said display signals for projecting a
18 pair of binocular images; and
19 a beam splitter means affixed to said
20 head mount and positioned for reflecting said
21 binocular images to said viewing screen.
- 1 2. The head-mounted projection display system of
2 Claim 1 wherein said viewing screen is a curved retro-
3 reflective screen.
- 1 3. The head-mounted projection display system of
2 Claim 1 wherein said viewing screen is a flat reflective
3 surface.
- 1 4. The head-mounted projection display system of
2 Claim 1 wherein said binocular image means is a cathode
3 ray tube.

1 5. The head-mounted projection display system of
2 Claim 1 wherein said binocular image means are two
3 cathode ray tubes.

1 6. The head-mounted projection display system of
2 Claim 1 wherein said head mount is a helmet.

1 7. A method of providing a head-mounted
2 projection display system for use with a viewing screen
3 for providing a display to an observer, said method
4 comprising the steps of:
5 providing a head mount to be worn by
6 said observer;
7 providing a head position sensor means
8 coupled to said head mount for generating
9 angular position signals indicative of the
10 angular position of the observer's head;
11 providing an image generator connected
12 to receive said angular position signals for
13 providing display signals representative of
14 binocular dynamic displays for the observer;
15 providing at least one binocular image
16 means connected to receive said display
17 signals and affixed to said head mount for
18 projecting a pair of binocular images; and
19 providing a beam splitter means affixed
20 to said head mount and positioned for
21 reflecting said binocular images to said
22 viewing screen.

1 8. A head-mounted projection display system for
2 use with a viewing screen for providing a display to an
3 observer, comprising:

4 a head mount to be worn by said
5 observer;

6 a head position sensor means coupled to
7 said head mount for providing angular position
8 signals indicative of the angular position of
9 the observer's head;

10 an image generator and signal processor
11 means connected to receive said angular
12 position signals for processing said angular
13 position signals and providing display signals
14 representative of binocular dynamic displays
15 for said observer;

16 at least two binocular image means
17 connected to receive said display signals and
18 affixed to said head mount for projecting a
19 pair of binocular images; and

20 a beam splitter means affixed to said
21 head mount and positioned for reflecting said
22 binocular images to said viewing screen.

1 9. The head-mounted projection display system of
2 Claim 8 wherein said head mount is a helmet.

1 10. The head-mounted projection display system of
2 Claim 8 wherein said viewing screen is a curved retro
3 reflective screen.

1 11. The head-mounted projection display system of
2 Claim 8 wherein said viewing screen is a flat reflective
3 surface.

1 12. The head-mounted projection display system of
2 Claim 8 wherein said binocular image means is a cathode
3 ray tube.

1 13. A head-mounted projection display system for use
2 with a retro-reflective viewing screen for providing a
3 display to an observer, comprising:
4 a head mount to be worn by the observer;
5
6 a head position sensor means coupled to said
7 head mount for providing angular position signals
8 indicative of the angular position of the observer's
9 head;
10 an image generator means providing display
11 signals representative of binocular dynamic displays for
12 the observer and connected to receive said angular
13 position signals;
14 a first binocular image means affixed to said
15 head mount connected to receive and split into two
16 images said display signals for projecting a pair of
17 binocular images;
18 a second binocular image means affixed to said
19 head mount connected to receive and split into two
20 images said display signals for projecting a pair of
21 binocular images;
22 a means for optically combining said display
23 signals connected to receive said display signals from
24 said first and said second binocular image means;
25 at least one means for projecting said
26 combined display signals from said optically combining
27 means; and
28 a beam splitter means affixed to said head
29 mount and positioned for reflecting said binocular
30 images to the viewing screen.

1 14. The head-mounted projection display system of Claim
2 13 wherein said first binocular image means further
3 comprises an inset optical relay.

1 15. The head-mounted projection display system of Claim
2 13 wherein said second binocular image means further
3 comprises a background optical relay.

1 16. The head-mounted projection display system of Claim
2 13 wherein said viewing screen is a curved retro-
3 reflective screen.

1 17. The head-mounted projection display system of Claim
2 13 wherein said viewing screen is a flat retro-
3 reflective screen.

1 18. The head-mounted projection display system of Claim
2 13 wherein said first binocular image means is a cathode
3 ray tube.

1 19. The head-mounted projection display system of Claim
2 13 wherein said second binocular image means is a
3 cathode ray tube.

1 20. The head-mounted projection display system of Claim
2 13 wherein said head mount is a helmet.

1 21. The head-mounted projection display system to Claim
2 13 wherein said beam splitter means further comprises a
3 first and second beam splitter said first and said
4 second beam splitter so positioned inclined in a
5 vertical plane approximately 45 degrees and further
6 inclined in the horizontal plane approximately 90
7 degrees.

1 22. A method of providing a head-mounted projection
2 display system for use with a retro-reflective viewing
3 screen for providing a display to an observer, said
4 method comprising the steps of:

5
6 providing a head mount to be worn by the
7 observer;

8
9 providing a head position sensor means coupled
10 to said head mount for providing angular position
11 signals indicative of the angular position of the
12 observer's head;

13 providing an image generator means providing
14 display signals representative of binocular dynamic
15 displays for the observer and connected to receive said
16 angular position signals;

17 providing a first binocular image means
18 affixed to said head mount connected to receive and
19 split into two images said display signals for
20 projecting a pair of binocular images;

21 providing a second binocular image means
22 affixed to said head mount connected to receive and
23 split into two images said display signals for
24 projecting a pair of binocular images;

25 providing a means for optically combining said
26 display signals connected to receive said display
27 signals from said first and said second binocular image
28 means;

29 providing at least one means for projecting
30 said combined display signals from said optically
31 combining means; and

32 providing a beam splitter means affixed to
33 said head mount and positioned for reflecting said
34 binocular images to the viewing screen.

FIG. 1

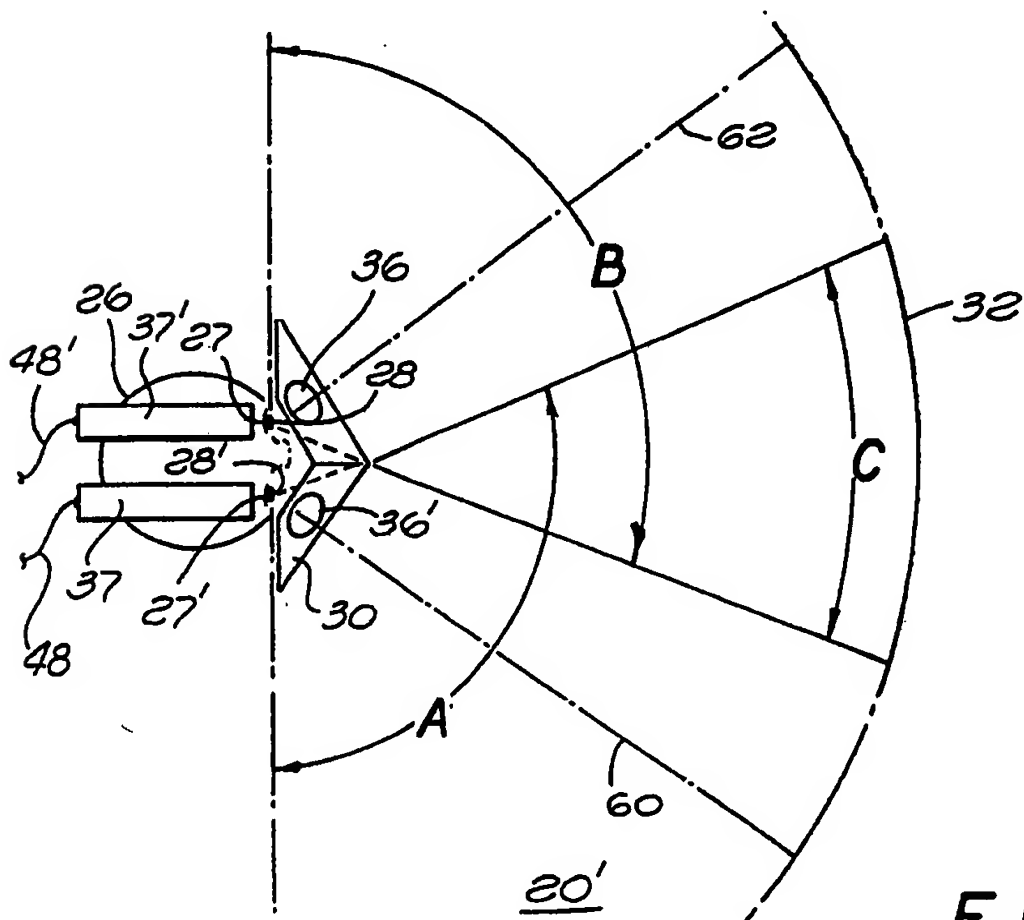
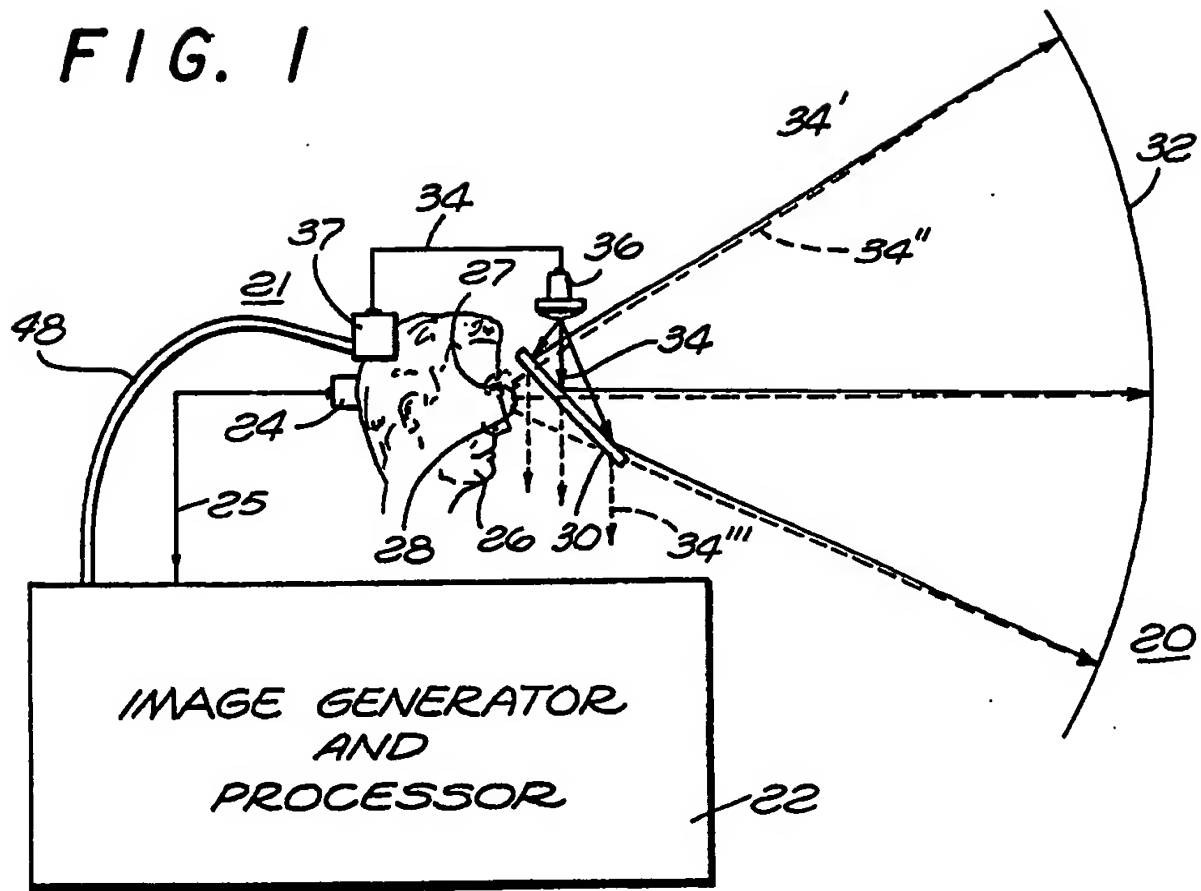
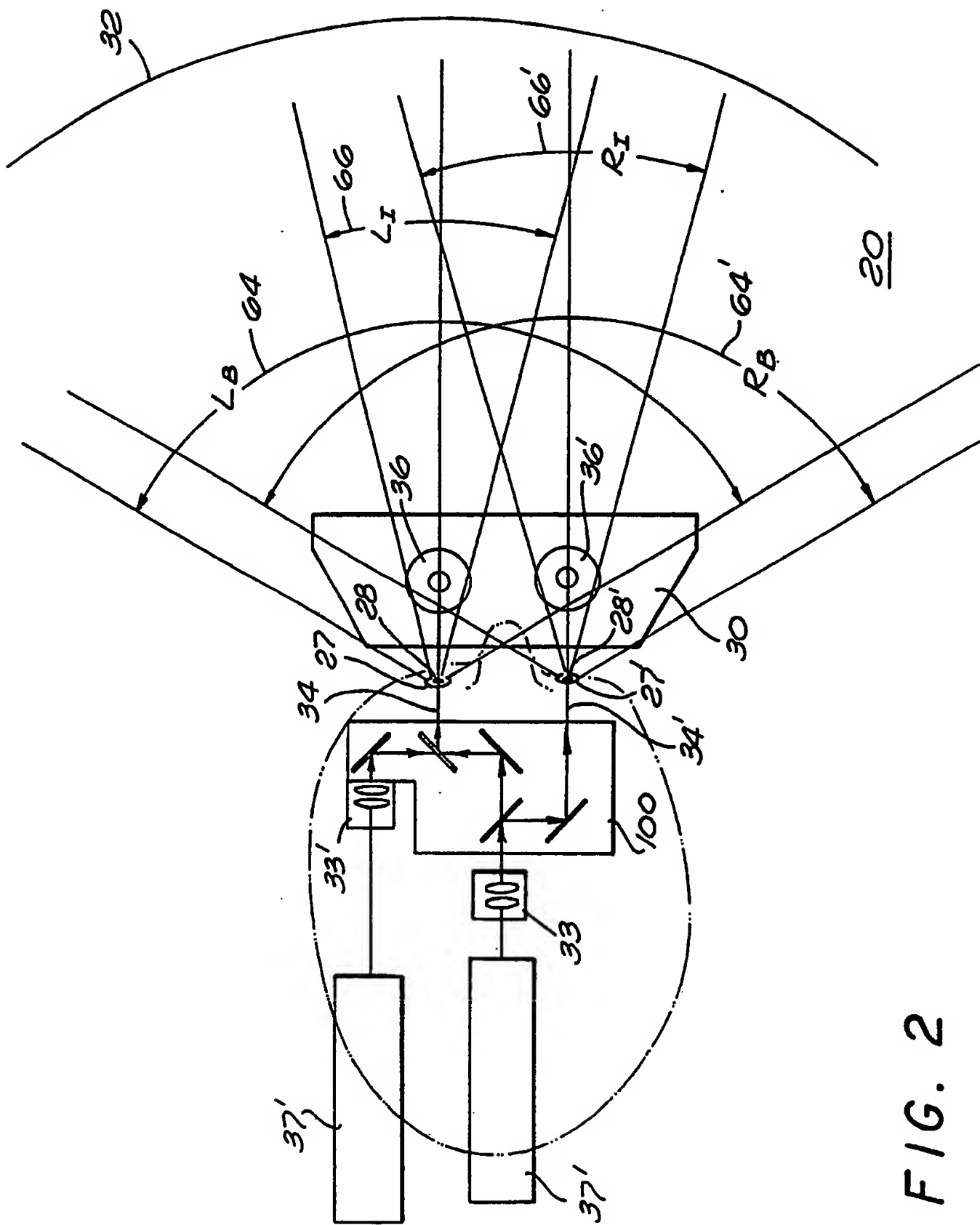
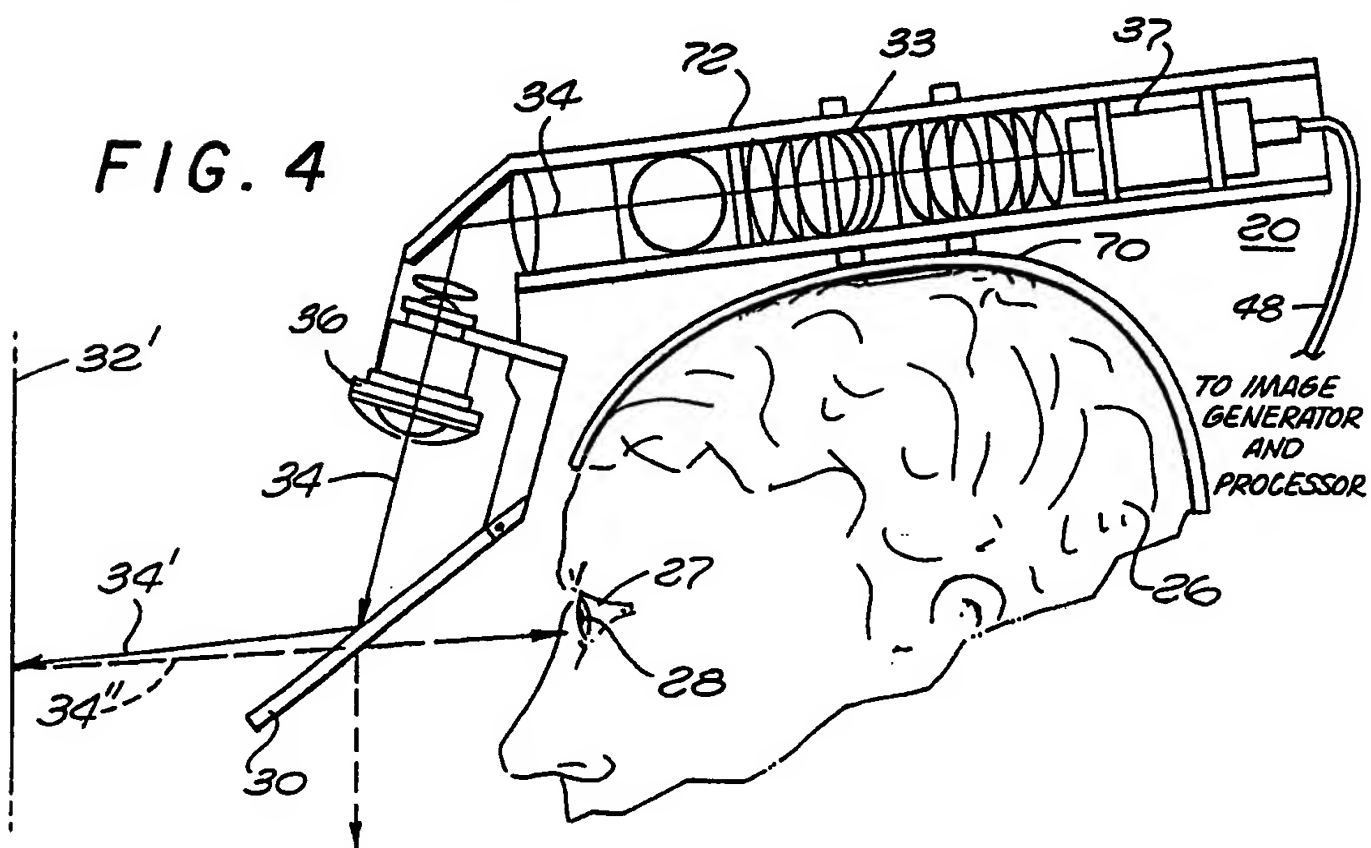
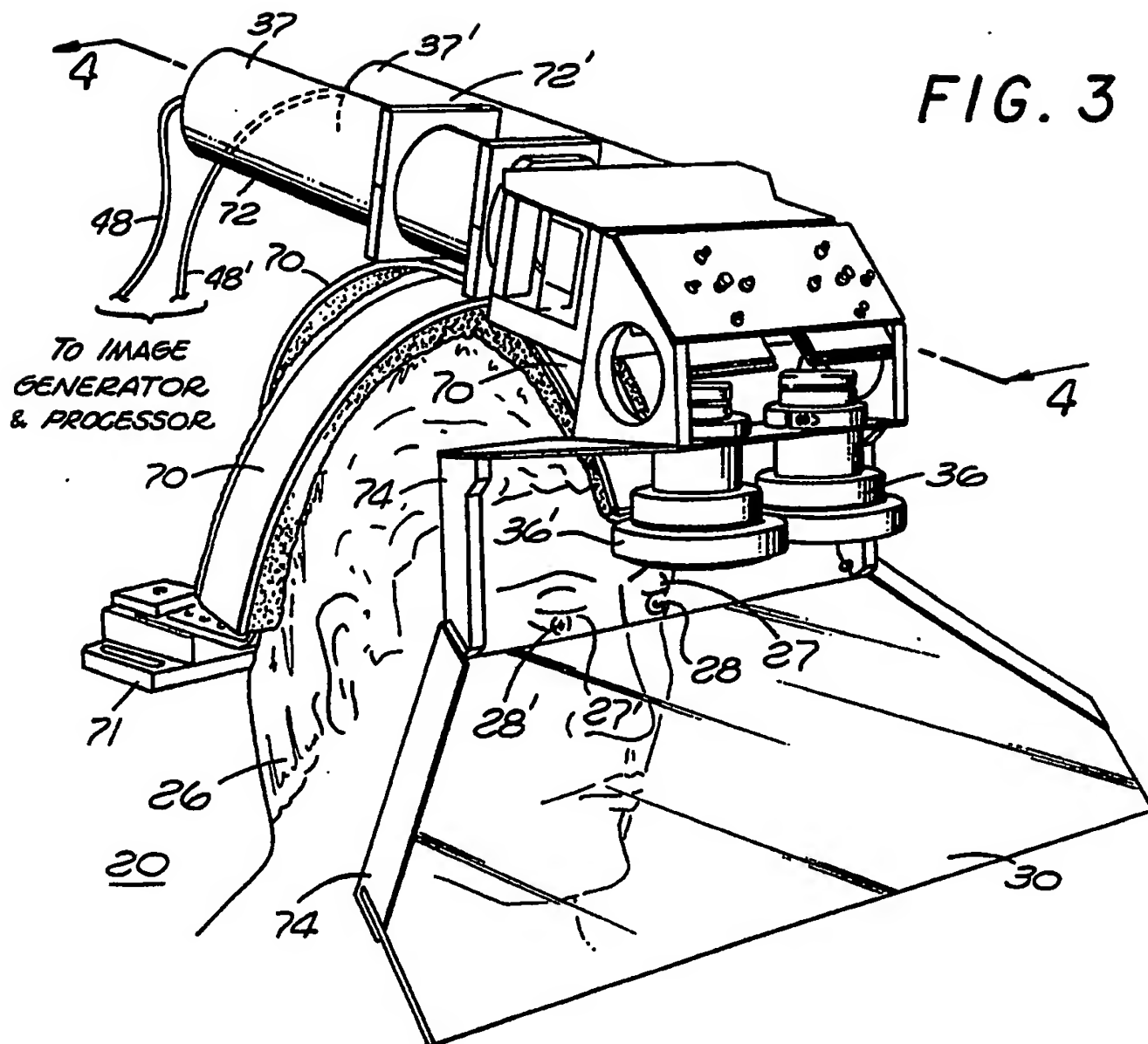


FIG. 5





INTERNATIONAL SEARCH REPORT

International Application No. PCT/US92/03226

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) *

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC (5): G09G 3/02; G01C 21/00; G09B 9/08

U.S.Cl.: 340/705; 340/980; 434/40

II. FIELDS SEARCHED

Minimum Documentation Searched ⁷

Classification System

Classification Symbols

U.S.Cl.

340/705,980
359/13,14,630,631
434/38,40,43,44Documentation Searched other than Minimum Documentation
to the extent that such Documents are included in the Fields Searched ⁸III. DOCUMENTS CONSIDERED TO BE RELEVANT ⁹

Category ¹⁰	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
X	US, A, 4,348,185 (BREGLIA ET AL.) 07 September 1982	1,2,6,7
Y	See figure 1, column 1, lines 52-57; column 2; lines 1-5; column 4, lines 24-40.	8-10,13,16,20, 22
Y	US, A, 4,439,157 (BREGLIA ET AL.) 27 March 1984 See column 1, lines 7-15 and column 3, lines 19-33.	8-9, 13-15, 20,22
Y	US, A, 4,969,714 (FOURNIER, JR. ET AL.) 13 November 1990. See figure 2 and column 3, line 54-59.	4,5,12,18,19
Y	US, A, 4,930,888 (FREISLEBEN ET AL.) 05 June 1990 See figure 1.	3,11,17
Y	US, A, 4,994,794 (PRICE ET AL.) 19 February 1991 See column 2, lines 46-59.	21
A	US, A, 4,303,394 (BERKE ET AL.) 01 December 1981	1, 7,13,22
A	US, A, 4,340,878 (SPOONER ET AL.) 20 July 1982	1,7,13,22
A	US, A, 4,348,186 (HARVEY ET AL.) 07 September 1982	1,7,13,22

* Special categories of cited documents: ¹⁴"A" document defining the general state of the art which is not
considered to be of particular relevance"E" earlier document but published on or after the international
filing date"L" document which may throw doubts on priority claim(s) or
which is cited to establish the publication date of another
citation or other special reason (as specified)"O" document referring to an oral disclosure, use, exhibition or
other means"P" document published prior to the international filing date but
later than the priority date claimed"T" later document published after the international filing date
or priority date and not in conflict with the application but
cited to understand the principle or theory underlying the
invention"X" document of particular relevance; the claimed invention
cannot be considered novel or cannot be considered to
involve an inventive step"Y" document of particular relevance; the claimed invention
cannot be considered to involve an inventive step when the
document is combined with one or more other such docu-
ments, such combination being obvious to a person skilled
in the art.

"A" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search

25 June 1992

Date of Mailing of this International Search Report

16 JUL 1992

International Searching Authority

ISA/US

Signature of Authorized Officer

Steven J. Saras

FURTHER INFORMATION CONTINUED FROM THE SECOND SHEET

A	US, A, 4,349,815 (SPOONER) 14 September 1982	1,7,13,22
A	US, A, 4,446,480 (BREGLIA ET AL.) 01 May 1984	1,7,13,22

V ☐ OBSERVATIONS WHERE CERTAIN CLAIMS WERE FOUND UNSEARCHABLE¹

This international search report has not been established in respect of certain claims under Article 17(2) (a) for the following reasons:

1. ☐ Claim numbers _____, because they relate to subject matter^{1,2} not required to be searched by this Authority, namely:

2. ☐ Claim numbers _____, because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out^{1,2}, specifically:

3. ☐ Claim numbers _____, because they are dependent claims not drafted in accordance with the second and third sentences of PCT Rule 6.4(a).

VI. ☐ OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING³

This International Searching Authority found multiple inventions in this international application as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims of the international application.
2. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims of the international application for which fees were paid, specifically claims:
3. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claim numbers:
4. ☐ As all searchable claims could be searched without effort justifying an additional fee, the International Searching Authority did not invite payment of any additional fee.

Remark on Protest

- ☐ The additional search fees were accompanied by applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ BLACK BORDERS
- ☐ IMAGE CUT OFF AT TOP, BOTTOM OR SIDES
- ☐ FADED TEXT OR DRAWING
- ☐ BLURRED OR ILLEGIBLE TEXT OR DRAWING
- ☐ SKEWED/SLANTED IMAGES
- ☐ COLOR OR BLACK AND WHITE PHOTOGRAPHS
- ☐ GRAY SCALE DOCUMENTS
- ☒ LINES OR MARKS ON ORIGINAL DOCUMENT
- ☐ REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY
- ☐ OTHER: _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.